other shortly posterior to second cell. The so-called tail-spot, another unstained area, is 14 to 28μ from tip of tail. Tail contains few stained elements.

Host.—Definitive: Turtle (*Terrapene carolina*); intermediate: unknown.

Location.—Adults in cavities of heart; ensheathed larvae in blood of primary host.

Distribution.—United States (Pennsylvania ?) and vicinity of Washington, D. C.

Specimens.—U. S. N. M. Helm. Coll. No. 32604.

Table 1 shows the principal measurements of seven larvae, and certain size relationships in percentages.

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ZOOLOGY.—*Egg-laying habits and larval stages of a milliped,* Arctobolus marginatus *(Say) Cook, native at Washington.*[1]

H. F. Loomis, Bureau of Plant Industry. (Communicated by O. F. Cook.)

Early in the summer of 1916, Mr. H. S. Barber, of the U. S. National Museum, was collecting insects in the woods on the Virginia shore of the Potomac River at Plummer's Island, a short distance above the city of Washington, when beneath the loose bark of a fallen tree he discovered a female milliped of the large, cylindrical, native species, *Arctobolus marginatus* (Say) Cook, in the act of laying her eggs. As soon as he realized what the milliped was doing he replaced the bark without disturbing her, and ceased further investigation of the log. Several days later, on June 2, I visited the same spot with Mr. Barber and we began a careful search of the rotting tree trunk for millipeds or their eggs, both of which were found to be numerous,

[1] The notes forming the basis for this paper were made a number of years ago and are far from complete, but deal with interesting phases in the life history of an animal belonging to a little-known group of arthropods. As an opportunity for continuing the study may not present itself again it seems desirable to put these observations on record. Received October 5, 1932.

as also were recently hatched young. The bark loosely covered the partially rotted interior, into which the millipeds had worked their way, and by the movement of their bodies had formed small chambers in the soft material. In some of these chambers the females had begun to lay eggs, whereas in others egg-laying had not started. Of all the millipeds found in this log, none were males. Likewise, in a search of the leaf-mould in the vicinity only females of this species were found and some of these also were laying.

On this visit no attempt was made at detailed observations, but gravid female millipeds, eggs, and recently hatched young were placed in tin boxes with a quantity of the moist, rotten wood, for further study.

Some of the females had already laid part of their eggs in the log but others apparently had not begun to lay, so that a count of the eggs subsequently laid in the individual boxes in which the females were kept gave an indication of the number of eggs that might be produced by a female at one "nesting." The greatest number of eggs laid by any one of these females was 261, while seven others produced the following numbers—216, 204, 203, 189, 186, 153, 74. These eggs were deposited between June 2 and 11, after which no more eggs were laid.

From observations on the imprisoned millipeds and those in natural surroundings it was apparent that this species had a definite egg-laying season, but there may have been at least one other such period in the fall, for on August 4, 1916, Mr. Barber noted numbers of these millipeds in the same locality mating on the tree trunks at night, and it is supposed that the eggs then fertilized were laid a few weeks later, instead of being held through the winter for laying the following spring, ten months after fertilization. Also it is probable that these were of the same generation of females which had been seen laying eggs in early June.

In this species of milliped it was found that the mother enclosed each egg in an individual pellet composed of what was, at first, thought to be the material constituting the excrement pellets, but closer examination showed the egg pellets to be of a lighter colored, coarser substance, containing tiny fragments of rotten wood, leaves, (and fungi?). Several times, by carefully opening the tin containers, the millipeds were caught in the act of forming these egg cases and were watched undisturbed practically throughout the entire process of encasing the egg in the pellet.

The first step in the manufacture of one of these egg cases was the

regurgitation of a small mass of material by the mother, who curved her head so that the mass was delivered to the legs a short distance behind the head, the eighth to eleventh pairs of legs receiving the moist lump. These legs held the mass while the milliped curved her head around still further and began flattening and spreading the material by repeatedly forcing the smooth, convex front of her head against it, until soon there was formed a thin saucer or shallow bowl, smoothed on the convex side by the milliped's head, but with a rough exterior. In the center of this saucer the egg was placed immediately following its ejection from one of the paired oviducts which in millipeds, contrary to what might be expected from the position of the oviducts in most other arthropods, are located just behind the second segment, at the front of the body. The actual placing of the egg in the saucer was not observed but probably was accomplished by the mother's bending her body over the saucer and laying the egg directly in it, although it might have been possible to have the egg passed back from the oviduct and placed in the saucer by the legs between the oviduct and those holding the receptacle. As soon as the egg was deposited, the edges of the saucer were brought up and kneaded together by the feet, while the junction was rapidly worked over by the front edge of the head or labrum, and this action of head and feet was continued until an almost perfect sphere, with a slightly roughened surface but without folds or cracks, was formed. The completed pellet was dropped by the mother and she soon began a repetition of the process for the next egg.

The completed egg pellets measured 3 to 3.5 mm. in diameter, with walls slightly less than a millimeter thick, leaving the egg lying loose in a chamber 1.5 to 1.8 mm. in diameter. The egg pellets were somewhat intermixed with excrement pellets but were distinguished from them by being nearly round, by having a rougher surface caused by the varied material from which they were made, and by the fact that these pellets, when exposed to the air, dried to a light brown color much faster than the excrement pellets, which had a finer texture that held moisture better, were oval in shape, and whose surfaces were smoother. The walls of the egg pellets formed the first food eaten by the young millipeds; each pellet containing enough food to last the milliped through several of its earliest stages of growth.

Occasionally the egg-laying and pellet-making processes were not conducted with routine exactness as was shown in one pellet where two eggs had been deposited by the mother, one being left slightly

exposed and forming part of the surface of the pellet. In another pellet the egg was visible through a carefully rounded, smooth-edged hole in the side, which possibly was left because of insufficient material to complete the pellet. At another time the mother had fashioned a pellet which outwardly was indistinguishable from the other egg pellets, but on breaking this pellet it appeared that no egg had been deposited in the perfectly moulded chamber.

The eggs were creamy white in color and broadly oval in shape, being about 1.3 mm. in their longest diameter and 1.1 mm. in the shortest diameter. All descriptions that have been noted in milliped literature refer to the eggs of millipeds as being round instead of oval. Moreover, all the eggs that have been found by the writer in collecting these animals have also been round, with this one exception. The formation of an edible pellet about each egg does not appear to have been reported for any other milliped, and from a quotation on a succeeding page, from a paper by J. W. Bailey, it appears that this custom is not followed throughout even the genus *Arctobolus*. Millipeds belonging to some of the other orders make definite nests in which they lay their eggs, but the eggs are not placed in individually manufactured cells, nor is any provision made by the mother for supplying the newly hatched young with food.

The egg pellets made by each of the females imprisoned in the tin boxes on June 2 were removed several days later and placed in separate boxes where they were examined from time to time. On July 9, first stage "larval" millipeds were found by breaking the egg pellets and a few second and third stage young were also seen there. Although some of these young necessarily had been present in previous examinations of the boxes they had been overlooked because it was expected that the young millipeds would emerge from the pellets as soon as they were born, whereas it was first discovered on July 9 that the young millipeds normally remained in the pellets for a considerable time after hatching and there underwent several changes. Subsequently it was determined that they remained in the pellets throughout the first two stages of their life and finally ate their way out during the third stage—usually in the latter part of this stage—when nearing the time for the third moult. Eggs continued to hatch until July 13, on which date no unhatched eggs could be found in the tins and there were only about a quarter as many millipeds in the first stage of growth as in either the second or third stages, indicating that the majority of the eggs had hatched considerably before this

date. From the rather limited observations it appeared that the period of incubation lasted from three to five weeks, but no very conclusive data were obtained.

The incubation period of the eggs in the tin boxes manifestly was about a week less than for similar eggs left in the log from which came the females used for observation. Warmer temperatures doubt-

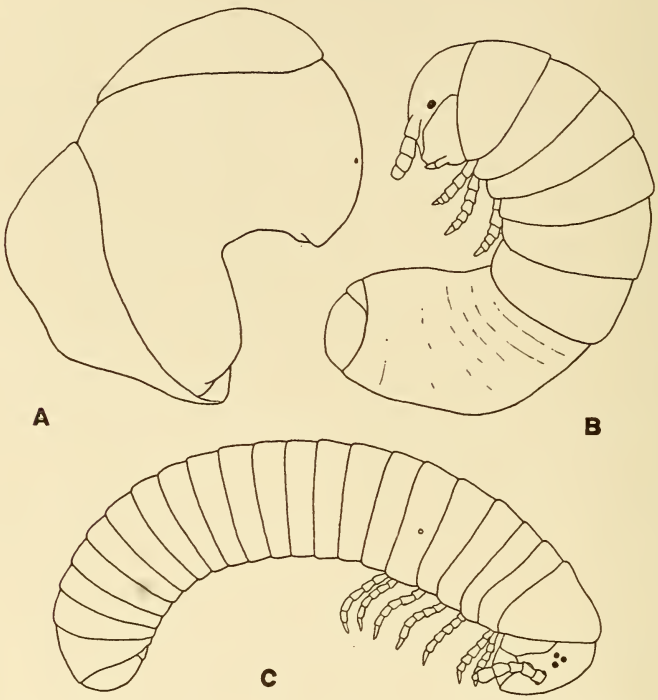

Fig. 1.—Three stages of *Arctobolus marginatus*. A. First stage, with portions of the egg-shell still adhering, head and segments not differentiated, the eye spot faintly indicated, the appendages still unformed. B. Second stage, with 6 definite segments and 3 pairs of legs. C. Third stage, with 21 segments and 7 pairs of legs.

lessly accounted for the more rapid incubation of the eggs in the tin boxes. Hence, it was assumed that from four to six weeks usually were required for the incubation of the eggs of this milliped under natural conditions.

When an egg hatched the shell usually split almost all the way around the middle, forming subequal halves narrowly joined together, the halves opening up, like a clam, exposing the young milliped in its first stage of life. During this stage the brownish eggshell

was not cast off but remained on the back of the milliped until the first moult had taken place.

Contrary to statements found in zoological text books and scientific papers on immature millipeds, the first stage "larva" of *A. marginatus* did not have a distinct head followed by definite segments, and there were no legs or antennae visible. Instead, the animal appeared as a short, white grub, somewhat angular in the region of the mouthparts; covered by a very delicate semi-transparent membrane or skin of uniform texture, through which a single eyespot on each side of the head and a suggestion of segments could be seen (Fig. 1). Although this skin was retained by the animal until the first moult it did not appear to be attached to the animal and was removed from several of the young to allow direct examination of them. They were found to have a distinct head and six well-formed segments, followed by a slightly swollen, abdomen-like portion, composed of indistinct rings, terminating in a soft but rather evident, truncate last segment containing well-defined anal valves and preanal scale. A brownish eyespot was found on each side of the head although this did not develop to a normal ocellus until the moult. The very short antennae appeared to be indistinctly 4-jointed, but the mouthparts were soft, unchitinized, and amorphous, and it was doubtful if the animals ate anything during this stage. There were no legs, but on segments 1, 2, and 3, small, elevated prominences or tubercles were noted in the locations where the legs would develop at the first moult.

The period of time passed by the animals in this first stage and in succeeding stages was not determined as the writer's unexpected departure from Washington occurred before the study of this feature of development was well under way.

Following the first moult, in the second stage of their existence, the young millipeds were short, white in color, and each had a well-developed ocellus on either side of the head, in addition to which, at times, there were two brownish eyespots which would develop into ocelli at the second moult. The mouthparts were of definite shape and moderately chitinized, and the mandibulary stipes slightly hollowed to receive the antennae. The antennae were quite short and capable of being somewhat telescoped, and there were five joints, with the four apical sense cones readily seen. Behind the head were six well-developed and definitely chitinized body segments, each of the first three with a pair of 6-jointed legs, as in mature individuals; the legs terminating in a strong, appendiculate claw, the needle-like appendage of which was below and nearly half the length of the main part

of the claw. All the joints of the legs had one or two strong setae on the ventral face. Segment 6 of the body had no indication of repugnatorial pores. The posterior half of the body resembled a soft, indistinctly ringed abdomen, with the last segment, valves, and preanal scale as described for the first stage young.

In the third stage, which succeeded the second moult, the still uncolored young millipeds could no longer be mistaken for insect larvae as they had a strongly chitinized body, composed of twenty-one distinct segments, infrequently twenty-two segments, and each of the first five of these bore a single pair of legs, while segment 6 bore two pairs of legs. The ensuing segments constituted two-thirds of the length of the body and were footless and showed no indication of where the legs to be added at the next moult would come. The second segment was not produced forward below segment 1, as it would be in after life. The last segment, anal valves, and preanal scale were shaped as in mature animals. A repugnatorial pore was visible on each side of segment 6 but there was no indication of pores on the segments thereafter. The antennae had six distinct joints, and the three fully developed ocelli formed a triangle on each side of the head; the mandibulary stipes were deeply excavated for the reception of the antennae. It was when nearing the end of this stage that the millipeds ate their way out of the food pellets made by the mother when the eggs were laid.

The fourth stage millipeds had twenty-six or twenty-seven segments and, in either case, the last six segments were legless. Thus females had thirty-five or thirty-seven pairs of legs, as the first five segments each had one pair of legs while the succeeding segments each had two pairs as far as the legs extended. Although many fourth stage millipeds were examined no males were detected, but it is possible that they would have had thirty-three or thirty-five pairs of legs, for the leg arrangement would be the same as for females except that segment 7 probably would be without legs because in the final stages of growth the males have the legs of this segment greatly modified and hidden within the body, the structures generally being referred to as "gonopods" and only functioning during mating. The animals were light brown, finely mottled with uncolored spots above and below, except on the posterior legless segments which were uncolored. In this stage the forward production of the second segment below the corner of segment 1, so evident in mature individuals, was first observed. The repugnatorial pores were present from segment 6 to the last pedigerous segment inclusive. The antennae had six obvious

joints, and on each side of the head six ocelli usually formed an equilateral triangle, but in some specimens the number of ocelli in each eye was reduced to three or four.

The structural notes on the growth stages following the fourth moult were never completed, but segment counts of a small number of young millipeds indicated that there were at least three more stages before maturity was reached.

Millipeds in the fifth stage had thirty-two segments, and their eyes were composed of eight to ten ocelli.

Of eight sixth-stage young, two had thirty-six segments, four had thirty-seven segments, and two had thirty-eight segments; the ocelli numbered thirteen to fifteen, with one individual in which there were but eight ocelli on one side of the head and ten ocelli on the other.

In what was assumed to be the seventh stage, three millipeds had forty-one segments, one had forty-three segments, and three had forty-four segments, and the ocelli ranged from eighteen to twenty-one.

Mature specimens of this species have been reported with forty-seven to fifty-seven segments and thirty to forty ocelli composing each eye. Those examined by the writer usually had between fifty and fifty-five segments and thirty-six to forty-three ocelli. In view of these figures it is probable that an eighth and possibly a ninth stage occurs in the life history of this species before maturity is reached.

In regard to the moulting of these millipeds, particularly in the early stages, it was observed that just prior to the moult the posterior legless portion of the body became noticeably elongated, with the segments considerably exposed, as much as the pedigerous segments, whereas after the moult these legless segments were strongly telescoped and hidden within each other, and the body was a lighter color than immediately preceding the moult. Following the moult the body remained quite soft for a day or two but gradually hardened and, in the later growth stages, assumed an increasingly darker color.

In early May several years prior to the observations reported in this paper, H. S. Barber, interested in the life history of *A. marginatus* in relation to the food habits of the giant glow-worm, *Phengodes laticollis* Lec. endeavored to find where and how the eggs of this millipeds were laid by placing about twenty full grown specimens of both sexes in a deep jar set in the ground and filled with leaf-litter for food. His subsequent observations are quoted below.

"By the end of July young had appeared in the jar although it had previously been examined without finding eggs. At this time, however, it was

discovered that in most cases the excrement pellets were not solid but consisted merely of a thin shell surrounding a comparatively large cavity in which the small brown-skinned egg was lying loose. These pellets showed no external difference from the solid normal pellets cast by large individuals of the species, but when exposed to the air for a few minutes the color changed slightly on account of the more rapid drying out of the thin shell. About a pint of both kinds of pellets was placed in tin boxes where they could be frequently examined. By the middle of August most of the young myriapods had devoured their enclosing pellets and were feeding on the solid ones. They measured 8 mm. in length and had seven pairs of legs, but some were moulting into a slightly longer, many-legged (35 pairs) form. Before the middle of September they had reduced all of the frass pellets in the tin into a mass of very fine frass and were crawling on its surface seeking other food. They congregated on bits of rotten wood that were introduced and began feeding, but the condition of this rotten wood was apparently unsuitable, and a few days later all were found dead on the surface, many having had all their legs eaten off by those who survived the longest."[2]

Several points of divergence may be noted which partly arose from the fact that the egg-laying habits had not been observed. Also it is appropriate to note the observations of another writer on what is probably a different species of the genus *Arctobolus* although referred to *marginatus*.

J. W. Bailey[3] listed *Spirobolus marginatus* as the only species known to occur in the state, and on page 13 made the following statements in discussing the habits of the Diplopoda.

"*Spirobolus*, one of the most common and the largest of the Diplopoda found in New York State, deposits its eggs in damp, wet places, usually in some decaying stump or fallen log. The pearly white eggs, about the size of a small buckshot, are deposited in June, July and August; usually 15 to 20 in a batch. The eggs are never covered with dirt, as in *Julus* or other species. The period of incubation is said to be ten to 18 days. The young emerge from the eggs as partially developed larvalike creatures having only three pairs of appendages as do other members of the class Diplopoda."

That the true *Arctobolus* (*Spirobolus*) *marginatus* is not native to New York State, but is a more southern species, was pointed out by O. F. Cook in describing *A. onondaga*, from Onondaga County, New York, as the type of the genus.[4] The strikingly different egg-laying habits of the New York species is an additional reason to consider it distinct from *marginatus*, but its identity with *onondaga* cannot be

[2] Barber, H. S., Fragmentary notes on the life history of the Myriapod, *Spirobolus marginatus:* Proc. Ent. Soc. Wash., vol. 17, no. 3, 1915.

[3] Bailey, J. W., The Chilopoda of New York State with notes on the Diplopoda: N. Y. State Mus. Bull. 276, 1928.

[4] Cook, O. F., Myriapoda of northwestern North America: Harriman Alaska Exped., pp. 64–65, 1904.

certified without comparing specimens with the description or the type specimen of *onondaga*.

East of the Mississippi, principally in the South Eastern and South Central states, there are about eight recognized species of millipeds belonging to the genus *Arctobolus;* whereas west of the Mississippi closely allied genera contain about the same number of species. In view of the differences in egg-laying habits between the New York species and the one about Washington, variation of the same habits of the other species undoubtedly occur, and investigation of these species should furnish interesting facts, which conceivably might also be of value in determining the systematic relationships of the species.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

493D MEETING

The 493d meeting was held at the Cosmos Club October 26, 1932, Vice-President HESS presiding.

Informal Communications.—W. C. MANSFIELD in company with Mr. HERMAN GUNTER, State Geologist of Florida, upon a recent trip up the Suwanee River, discovered, about a mile and a half upstream from White Springs, an unconformity between the tampa limestone and the sandstone of the overlying Hawthorne formation.

H. D. MISER described three sink-hole deposits in Ordovician limestone, all near Rolla, Missouri. One sink-hole contained flint clay with diaspore; another contained deposits of limonite, hematite, and magnetite, all probably derived from pyrite; and the third sink-hole contained coal of Pennsylvanian age. The coal deposit has the form of a vertical column 90 feet in diameter and 180 feet long, and is entirely surrounded by fire clay. All three deposits have been worked commercially.

Program: N. H. DARTON: *New geologic map of Texas.*

C. WYTHE COOKE: *Pleistocene changes of sea level.*—The alternating accumulation and melting of the continental ice caps during the Pleistocene epoch caused repeated fluctuations of sea level amounting to several hundreds of feet in amplitude. The sea was low during the glacial stages and high during the interglacial stages. During each resting stage that was of sufficient duration the sea engraved a high-water mark or a low-water mark on the land and thus recorded the position of its shore at various stages. But the height of sea level is also affected by any crustal movements that change the capacity of the oceanic basins. Therefore, the present altitude of the high-water marks or abandoned shore lines can not be attributed ex-